Programa de Pós-Graduação
Desenvolvimento Regional
mestrado e doutorado

DOI: 10.17058/redes.v28i1.17486

Rural Credit and Gross Value of Agricultural Production: an analysis of Brazilian States

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Abstract
Rural credit has been one of the main mechanisms of agricultural policy over the years, with significant contributions to the development and expansion of Brazilian agricultural production. Thus, this study analyzes the impact of total rural credit in the forms of financing, investment, and commercialization on the gross value of agricultural production in Brazilian states from 2005 to 2020. Methodologically, the panel data model and Granger causality test proposed by Dumitrescu and Hurlin (2012) were used. The results obtained through the panel data model indicated that only rural credit for investment and the harvested area had a positive and significant impact on the gross value of agricultural production. The Granger causality tests identified different causal relationships for the distinct credit modalities and different lag levels, leading to the conclusion that there is a significant temporal precedence between rural credit and the gross value of agricultural production in Brazilian states – regardless of the number of lags included in the model, rejecting the null hypothesis of homogeneous non-causality.
Keywords: Agricultural Policy. Financing. Panel Causality. Panel Data.

Crédito Rural e Valor Bruto da Produção Agropecuária: uma análise dos estados brasileiros

Resumo
Um dos principais mecanismos da política agrícola ao longo dos anos é o crédito rural, com importantes contribuições para o desenvolvimento e expansão da produção agropecuária brasileira. Deste modo, este estudo analisa o impacto do crédito rural total nas modalidades custeio, investimento e comercialização sobre o valor bruto da produção agropecuária dos estados brasileiros, de 2005 a 2020. Metodologicamente, utilizou o modelo de dados em painel e o teste de causalidade de Granger proposto por Dumitrescu e Hurlin (2012). Os resultados obtidos, por meio do modelo de dados em painel, indicaram que apenas o crédito rural para investimento e a área colhida exerceram impacto positivo e significativo sobre valor bruto da produção agropecuária. Quanto aos testes de causalidade de Granger, estes

identificaram diferentes relações de causalidade para as distintas modalidades de crédito e para os diferentes níveis de defasagens, levando a concluir que existe uma precedência temporal significativa entre o crédito rural e o valor bruto da produção agropecuária dos estados brasileiros - independente do número de defasagens incluídas no modelo, rejeitando a hipótese nula de não causalidade homogênea.
Palavras–chave: Política Agrícola. Financiamento. Causalidade em Painel. Dados em Painel.

Crédito Rural y Valor Bruto de la Producción Agropecuaria: un análisis de los estados brasileños

Resumen
Uno de los principales mecanismos de la política agrícola a lo largo de los años es el crédito rural, con importantes contribuciones al desarrollo y expansión de la producción agrícola brasileña. Así, este estudio analiza el impacto del crédito rural total en las modalidades de costeo, inversión y comercialización sobre el valor bruto de la producción agrícola en los estados brasileños, de 2005 a 2020. Metodológicamente, utilizó el modelo de datos de panel y la prueba de causalidad de Granger propuesta por Dumitrescu y Hurlin (2012). Los resultados obtenidos, a través del modelo de datos de panel, indicaron que solo el crédito rural para inversión y el área cosechada incidieron positiva y significativamente en el valor bruto de la producción agropecuaria. En cuanto a las pruebas de causalidad de Granger, identificaron diferentes relaciones de causalidad para los distintos tipos de crédito y para los distintos niveles de rezagos, concluyendo que existe una precedencia temporal significativa entre el crédito rural y el valor bruto de la producción agropecuaria en los estados Brasileños - independientemente del número de rezagos incluidos en el modelo, rechazando la hipótesis nula de no causalidad homogénea.
Palabras clave: Política agrícola. Financiación. Panel de causalidad. Datos del tablero.

1 Introduction

Brazilian agriculture has undergone a significant process of transformation and increased productivity, characterized by the technological advancement of the sector and the expansion of agricultural frontiers. In this process, agricultural policy has played a fundamental role, particularly rural credit policy. According to Buainain et al. (2014), rural credit has been one of the main instruments of agricultural policy for the rural producer, with significant contributions to the development and expansion of Brazilian agriculture. It serves as a support for the producer in the face of climatic and market adversities and is considered one of the bases for the good performance of agriculture.

Rural credit is an essential mechanism for the modernization and expansion of agricultural production. Producers with access to credit can invest in production, facilitating the purchase of inputs, machinery and equipment, improved seeds, and hiring labor, among other investments that can ensure productivity gains, making it easier to place their products in the market more competitively (ARAÚJO, 2019).

Vieira Filho, Gasques, and Ronsom (2020) and Gasques (2017) agree that Brazilian agriculture has experienced a successful history in recent decades. According to the authors, Brazil has stood out especially in the Total Factor Productivity (TFP), presenting an average annual growth rate of 4.3%. This rate is higher than those of other countries that stand out in the world scenario, such as Argentina (2.7%), Chile (3.1%), the United States (1.9%), and China (3.3%). They argue that investments in research and technology are among the main factors that boosted Brazilian agriculture's productivity.

In Brazil, agricultural activity has always been relevant to economic growth, generating foreign exchange, employment, and income. In 2020, agriculture registered an increase of 2.0%, while the industry and services sectors recorded a decline of 3.5% and 4.5%, respectively. Its participation in Brazil's Gross Domestic Product (GDP) increased from 5.1% in 2019 to 6.8% in 2020 (MAPA, 2020).

Parallel to the growth of agriculture, rural credit availability also increased, reaching the value of R$ 204 billion in 2020, divided into credit for investment (R$ 57.9 billion), credit for operating expenses (R$ 113.7 billion), and commercialization (R$ 21.8 billion). Importantly, there was a real growth in rural credit availability of 70.11% between 2005 and 2020 from just over R$ 120 billion to R$ 204 billion. The states that demanded the largest volumes of resources in 2020 were Paraná (R$ 30.9 billion), Rio Grande do Sul (R$ 27.9 billion), Minas Gerais (R$ 25.4 billion), and São Paulo (R$ 20.8 billion). Together, these states represent 51% of all rural credit transacted in the country (BACEN, 2021).

In this context, this study aimed to analyze the impact of rural credit on the gross value of agricultural production in Brazilian states from 2005 to 2020. Additionally, it aims to verify the causal relationships between total rural credit and its subcategories of financing, investment, and commercialization with the gross value of agricultural production. To achieve this, we employed the panel data model and the causality test proposed by Dumitrescu and Hurlin (2012), which tests the null hypothesis of homogeneous non-causality, meaning the absence of individual causality for all panel units.

In addition to contributing to the discussion on the topic, the relevance of this study lies in providing updated information on the impact of rural credit on the gross value of agricultural production in Brazilian states. Another important point is the identification of causal relationships between variables in a panel data context using the Dumitrescu and Hurlin (2012) method, which has not yet been identified for this topic. This method innovates by considering the specific characteristics of each variable and the cross-sectional dependence between panel units.

Apart from this introductory section, this study is divided into three more sections and final considerations. The second section presents an empirical analysis of the relationship between rural credit and agricultural output, highlighting the most recent studies on the subject through a literature review. The third section outlines the adopted methodological procedures, as well as the description of the analyzed methods and variables. The fourth section presents the results and discussions, and finally, the concluding remarks.

2 Rural Credit and Agricultural Production: An Empirical Analysis

This section conducted a narrative literature review to survey academic literature on the studied topic. Articles, theses, dissertations, and books were searched on digital platforms such as Google Scholar, Capes Café Periodicals Portal, Scopus, and Web of Science. The search criteria filtered publications from the last ten years (2011–2021) to retrieve the most recent literature on the subject. The following keywords were used for the search: rural credit, the impact of rural credit on the gross value of agricultural production, and rural credit and gross value of agricultural production.

Rural credit has been a significant instrument of agricultural policy for rural producers, contributing significantly to the development and expansion of Brazilian agriculture. It has helped farmers overcome adversities such as edaphoclimatic and market factors, inadequate infrastructure, high-interest rates, and unfavorable exchange policies for the sector. Therefore, studies on the impact of rural credit on agricultural production are increasingly relevant and frequent in economic and social studies (ARAÚJO et al., 2020; DORNELAS, 2020; ARAÚJO; ALENCAR; VIEIRA FILHO, 2020; PIRES, 2013; BATISTA; NEDER, 2014; RAMOS; MARTHA JÚNIOR, 2010; ROCHA; OZAKI, 2020; PINTOR; SILVA; PIACENTI, 2014).

According to Araújo et al. (2020), rural credit became an essential governmental instrument to support rural producers with the creation of the National Rural Credit System (SNCR) by Law No. 4,829/1965. Its purpose is to meet the demands of common and inherent risks to agricultural activities such as high volatility of agricultural prices, lack of competitiveness in the input supplier market, and deficiencies in infrastructure and logistics.

Freitas, Silva, and Teixeira (2020) and Teixeira, Miranda, and Freitas (2014) support the argument that rural credit is an important policy supporting Brazilian agriculture and enabling its expansion through the modernization of production structures. Rural credit is considered one of the pillars of the national agricultural policy.

SNCR aims to provide low-cost credit to producers to finance production, purchase machinery, and finance the costs of operation and commercialization of products in the market. It is a significant incentive for the modernization of Brazilian agriculture, allowing producers to access more technological resources to increase production (ARAÚJO; ALENCAR; VIEIRA FILHO, 2020).

The volume of credit granted to producers, subsidized by the government, has increased since its creation in 1965. However, this trend lasted only until the mid-1970s, when Brazil experienced an increasing phase of inflation and fiscal crisis. As a result, the supply of rural credit was reduced. It only began to grow again in the 1990s, after SNCR underwent policy reformulation, adopting new standards of agricultural financing. During this period, the private sector's increasing participation in financing resources stands out, as it was predominantly public until the mid-1990s (FREITAS; SILVA; TEIXEIRA, 2020; ARAÚJO; ALENCAR; VIEIRA FILHO, 2020).

Rural credit is an essential public policy for encouraging agricultural activity. Several studies in the national literature have evaluated the impacts of rural credit on the value of agricultural production. Among these studies, Borges and Parré (2021) evaluated the relationship between rural credit and agricultural production from 1999 to 2018, using the methodology of Autoregressive Vector, Granger Causality test, and Ordinary and Generalized Least Squares methods. The results indicated a positive impact of total rural credit on agricultural production of 0.20%. Therefore, a 1% increase in total rural credit supply increases agricultural production by 0.20%. The Granger causality test indicated that there is unidirectional causality from total rural credit to agricultural production.

Similarly, Reginato, Cunha, and Vasconcelos (2019) analyzed the relationship between rural credit and Brazilian agricultural production from 2002 to 2014. The authors used the panel data model and the Granger causality test proposed by Holtz-Eakin, Newey, and Rosen (1988) and Granger and Huang (1997). The results indicated that there is a temporal precedence between rural credit and agricultural production only for the test methodology developed by Holtz-Eakin, Newey, and Rosen (1988), considering two and three lags. On the other hand, the sum-difference test indicated no causality relationship from rural credit to agricultural production, regardless of the number of lags considered. However, both tests confirmed the existence of temporal precedence between agricultural production and rural credit, rejecting the null hypothesis of non-causality.

Gasques, Bacchi, and Bastos (2017) analyzed the impacts of rural credit on Brazilian agriculture from 1996 to 2015, using the transfer function model. They identified that for every 1% increase in rural credit, there is a positive impact of 0.40% on the gross value of production (GVP), 0.19% on the agribusiness product, 0.18% on the agricultural product, and 0.12% on the Total Factor Productivity (TFP). Thus, incentives for rural credit and, in general, national agricultural policy become of great relevance to stimulate the sector, given the positive impact that rural credit exerts on agricultural variables.

Medeiros et al. (2017) used the Vector Error Correction (VEC) model to investigate the impact of rural credit on agricultural production between 2006 and 2014. The findings suggest that changes in the planted area, sale of agricultural machinery and implements, and sale of fertilizers had a positive impact on agricultural production in the long term, while rural credit had no effect. However, investments in fertilizers, machinery and equipment, and the expansion of rural credit were observed to have a positive effect on agricultural production in the short term. The authors attributed this short-term effect to the destination of credit, which is directed more toward production costs than productivity gains and agricultural expansion.

Pintor, Silva, and Piacenti (2014) also investigated the impact of rural credit policy on Brazilian agriculture and GDP growth using panel data methodology. They found that the total rural credit had a positive impact on the gross value of agricultural production in Brazilian states, with a 1% increase in the total rural credit resulting in a 0.094% increase in the gross value of agricultural production and a 0.30% increase in the harvested area.

Melo, Marinho, and Silva (2013) used the Vector Autoregressive (VAR) model and the Granger causality test to analyze the causal relationship between rural credit and agricultural production. They found that the relationship varied depending on the analyzed type of credit, with credits for cost and commercialization having a bidirectional causality relationship with agricultural production, while investment credit had an inverse causality relationship.

Araújo et al. (2020) noted that the government has continuously improved the rural credit policy to enhance its effectiveness and reduce bureaucracy. They also highlighted the use of diverse methodological tools to analyze the impact of rural credit on the Brazilian economy.

3 Methodological Procedures

This study is based on a quantitative research approach, employing panel data analysis to verify the impact of rural credit on the gross value of agricultural production in Brazilian states from 2005 to 2020, as well as to verify the existence of a causality relationship between the two variables.

The period chosen for analysis comprises the years 2005 to 2020. The choice of the period is due, firstly, to the availability of data, as it is the only period that allowed equating all variables, considering the proposal for regional analysis. In addition, the Brazilian economy underwent profound transformations during these years, transitioning from a significant cycle of economic growth to a recessionary phase, reaching a negative growth rate of −4.5% in 2015 – the lowest index recorded in the last twenty years (IBGE, 2021).

3.1 Variables and Data Source

All variables used in this study have an annual frequency for the 26 Brazilian states and the Federal District, totaling 405 observations. The monetary variables are in Brazilian reais and at current prices in 2020, based on the General Price Market Index (IGP-M) calculated by the Getúlio Vargas Foundation (FGV). Table 1 presents the variables and their respective sources.

Table 1. Sources of variables and empirical evidence.

Variables	Source	Authors
Gross Value of Agricultural Production (GAP)	MAPA	Gasques; Bacchi; Bastos (2017)
Total Rural Credit (Cr_total)	BACEN/SICOR	Borges & Parré (2021)
Credit for Operating Costs (Cr_Custeio)		Reginato; Cunha; Vasconcelos (2019)
Credit for Commercialization (Cr_Comercialization)		Ribeiro & Conceição (2019)
Credit for Investment (Cr_Investment)		Medeiros et. al (2017)
Harvested Area (hectares)	IBGE/SIDRA	Medeiros et. al (2017) Pintor; Silva; Piacenti (2015)
Value of Exports	AGROSTAT	Pintor; Silva; Piacenti (2015)
International Commodity Prices	UNCTAD	Pintor; Silva; Piacenti (2015)

Source: Prepared by the authors.

The Gross Value of Agricultural Production (GVAP) corresponds to the gross revenue of crop and livestock establishments (MAPA, 2021). Rural credit is composed of financial resources intended for the rural sector and meets various purposes such as financing, investment, commercialization, and industrialization. This segmentation aims to meet the peculiarities of the Brazilian agricultural sector (BACEN, 2021).

As defined and regulated by the Rural Credit Manual (MCR), financing credit is the resources intended for financing the productive cycle of permanent or temporary crops and livestock exploitation, including the purchase of inputs related to the production phase. On the other hand, credit for commercialization aims to enable the necessary resources for product commercialization in the market. Finally, investment credit is the resources intended for the construction, renovation, or improvements in the enterprise, acquisition of machinery and equipment, irrigation and dam works, afforestation and reforestation, pasture recovery and crop formation, electrification, and telephony, among others. The total credit corresponds to the sum of the credit for financing, commercialization, and investment.

The harvested area variable corresponds to the sum of temporary and permanent crops. The export variable is the monetary value of agribusiness exports in dollars. For comparison purposes, this variable was converted to real by the annual commercial exchange rate obtained from the Institute of Applied Economic Research (IPEA).

Finally, the international commodity price variable corresponds to the average prices of agribusiness products in dollars, being converted to reais by the annual commercial exchange rate obtained from IPEA.

3.2 Panel Data: Method Description and Model Specification

In the panel data model, the same cross-sectional unit (a country, state, or company) is followed over time, thus presenting two dimensions: spatial and temporal. The panel data model is also known as stacked data, the combination of time series and cross-sectional data, microdata panel, longitudinal data, historical event analysis, and cross-sectional analysis, all of which essentially indicate the movement over time of cross-sectional units (GUJARATI and PORTER, 2011).

According to Gujarati and Porter (2011), the use of panel data models has some advantages over cross-sectional or time series data, such as: 1) it takes into account the heterogeneity of individuals in the sample; 2) it provides more informative data, greater variability, less collinearity, and more degrees of freedom; 3) it is more suitable for examining the dynamics of change, as it studies repeated cross-sectional observations; 4) it can better detect effects that simply cannot be observed in a cross-sectional or time series; 5) it allows studying more complex models; and 6) it minimizes the bias that could result from using an aggregate set of individuals.

This model can be estimated by several techniques, among which the pooled model, fixed effects model, and random effects model stand out. The pooled model is a simple regression estimated by the Ordinary Least Squares (OLS) method, in which the data is stacked and estimated in a single regression, considering all observations homogeneous. The main problem with this model is that it does not distinguish cross-sectional units, neglecting any heterogeneity that may exist between them (GUJARATI and PORTER, 2011).

In the fixed effects (FE) model, the intercept may be different between individuals since each cross-sectional unit has its own spatial characteristics, but no intercept changes over time. In the random effects (RE) model, the intercept values are randomly drawn from a larger population; the intercept in this case represents an average value of all cross-sectional intercepts (GUJARATI AND PORTER, 2011).

Chow, Hausman, and Breusch-Pagan LM tests were performed to choose the model that best fits the data. The Chow test evaluates which is the best estimation between pooled and fixed effects models. In this test, the null hypothesis assumes that the pooled model is the most appropriate and, therefore, there is homogeneity in the constant. In contrast, the constant is assumed to have heterogeneity if the null hypothesis is rejected, and, in this case, the most suitable model is the fixed effects model.

The Hausman test helps in choosing the best estimation between fixed effects and random effects models. The null hypothesis assumes that both models do not present substantial differences, in which case both estimators are consistent. The fixed effects model is the most suitable if the null hypothesis is rejected. Finally, the Breusch-Pagan LM test is used to verify which is the best estimation between pooled and random effects models. The null hypothesis in the LM test is that there are no variations between the cross-sectional units, i.e., there is no panel effect. Therefore, the most suitable model is the pooled one if the null hypothesis is accepted. On the other hand, the preferable model is the random effects if the null hypothesis is rejected.

According to Gujarati and Porter (2011), despite its advantages, the panel data model presents some problems of estimation and inference, as it involves both time and cross-sectional dimensions, and problems related to both dimensions, such as heteroscedasticity, autocorrelation, and non-stationarity, may be present in panel data and need to be addressed.

According to Gujarati and Porter (2011), a series is stationary when the mean, variance, and covariance are constant over time. The Im, Pesaran, and Shin (IPS) (2003) unit root test and the Levin, Lin, and Chu (2002) test were used to verify whether the series is stationary or not. The null hypothesis of the tests is that there is a unit root in all panels.

Another problem related to time series is autocorrelation. Autocorrelation exists when errors are correlated over time. The Wooldridge test, whose null hypothesis is the absence of autocorrelation, was used to diagnose the presence of autocorrelation.

On the other hand, heteroskedasticity is a common problem in cross-sectional data and occurs when the variance of errors is not constant. The Breusch-Pagan-Godfrey test was used to detect the presence of heteroskedasticity, and its null hypothesis is the absence of heteroskedasticity, meaning the error terms are homoskedastic.

Firstly, the series were transformed into logarithms, a strategy suggested by Gujarati and Porter (2011) to interpret the relationships between variables as elasticities, obtain the growth rate of the variable, achieve better distribution properties, and reduce the problem of heteroskedasticity. Thus, the equation to be estimated in this study follows the logarithmic form, as shown in Equation 1.

$$lVBPi = \beta 0 + \beta 1 lCr\_totali + \beta 2 lCr\_investimenti + \beta 3 lCr\_operatingi + \beta 4 lCr\_comercializationi + \beta 5 lharvested\_areai + \beta 6 lexporti + \beta 7 l\_price\_commoditiesi + \beta 8 dummy\_nordestei + \varepsilon i \quad (1)$$

Where:

lVBPi is the gross value of agricultural production of state i;
lCr_totali is the total rural credit supply of state i;
lCr_investimenti is the rural credit supply for investment of state i;
lnCr_operatingi is the rural credit supply for operating expenses of state i;
lCr_commercializationi is the rural credit supply for commercialization of state i;

lharvested_areai is the total harvested area in state i;
lexporti corresponds to the real value of exports of state i;
lprice_commoditiesi is the average price of commodities in the international market;
dummy_nordestei.

3.3 Granger Causality Test: Method Description

According to Gujarati and Porter (2011), the Granger causality test assumes that past events can cause present events. This test is used as a complement to the analysis to identify the direction of causality between rural credit and gross agricultural production. The concept of Granger causality refers to the ability of one variable to predict the behavior of another variable, such that there is a causal relationship if the lagged values of the variable x consistently predict the current values of y (SANTOS, MARQUETTI, OLIVEIRA, 2020).

Thus, we seek to verify temporal precedence to explain a given variable. In this case, we analyze whether rural credit supply can explain the behavior of gross agricultural production in Brazilian states.

The method employed in this study follows the model proposed by Dumitrescu and Hurlin (2012), who proposed a Granger causality test for panel data, where the specific characteristics of each individual and cross-sectional dependence are explicitly considered. Thus, both the heterogeneity of the regression model and the causal relationship are considered. The Dumitrescu and Hurlin (2012) method differs from the conventional model by allowing all coefficients to be different across cross-sections.

Given two stationary variables x and y observed for N individuals in T time periods, we have the following model:

$$yi,t = \alpha\mathrm{i} + \sum_{\mathrm{k}=1}^{\mathrm{k}} yi\ (\mathrm{k})\ +\ yi,t-k\ +\ \sum_{k-1}^{k} \beta i\ (k)\ xi,t-k +\ \varepsilon i,t \qquad (2)$$

Where: yi = (yi (1), ..., yi(k)); βi = (βi(1),...,βi(k)); xit and yit are the parameters associated with the variables of interest; αi are the fixed individual effects of the i=1,...,N cross-sectional units; K is the number of lags; and yi(k) and βi(k) are the autoregressive coefficients, which, although constant over time, differ between groups. In summary, if the variable x causes, in the sense of Granger, variable y, changes in x should precede changes in y. If, in the regression of y on lagged x and y, x is significant in predicting y, it is concluded that x causes, in the sense of Granger, y (GUJARATI and PORTER, 2011).

The Dumitrescu and Hulin (2012) method tests the null hypothesis of homogeneous non-causality (HNC), which means the absence of individual causality for all panel units. The null hypothesis of HNC is formulated as follows:

$$H0: \beta i = 0\ \forall i = 1, \dots N \qquad (3)$$

Where: βi = (βi(1), ..., βi(k)).

On the other hand, the alternative hypothesis indicates the presence of Granger causality for at least a proportion of the cross-sectional units of the panel. In the alternative hypothesis, the authors allow β_i to be different between groups (due to the heterogeneity of the model). In H1, there are $N_1 < N$ individual processes with non-causality from x to y. As this is a more comprehensive test, allowing non-causality for some units, the alternative hypothesis is defined as:

$$H_1: \beta_i = 0 \; \forall i = 1\ldots, N_1$$
$$\beta_i \neq 0 \; \forall i = N_1 + 1, N_1 + 2, \ldots, N \quad (4)$$

Where: N1 is not known but satisfies the condition $0 \leq N_1/N < 1$. The N1/N ratio is less than one, as N1 = N implies the absence of causality for all individuals in the panel, in which case the null hypothesis HNC is accepted. Conversely, there is causality for all individuals in the sample when N1 = 0. Thus, we have a homogeneous relationship for causality. On the contrary, the causality relationship is heterogeneous if N1 > 0, and both the regression model and the causality relationships differ from one individual to another, implying different causality relationships between the analyzed units (DUMITRESCU and HULIN, 2012).

The Dumitrescu and Hulin (2012) Granger causality test has the advantage of generating efficient estimators even in small samples for multivariate models and can even be applied to unbalanced panels with the adoption of different lag orders for different cross-section units. This makes it a robust approach that is perfectly applicable to the object of study in this research.

The Levin, Lin, and Chu (2002) tests, which assume the existence of common processes with the unit root, and the Im Pesaran and Shin (2003) test, which assumes the existence of an individual process with the unit root, with parameters varying randomly among individuals, were carried out to verify the presence of unit root (SANTOS, MARQUETTI, OLIVEIRA, 2020).

Subsequently, the cointegration test was performed to verify if the series presented long-term equilibrium. There are three widely used methods in the literature for panel data: Pedroni (1999), Kao (1999) and Johansen (1995) and Fisher (1932). All of them were applied in this study and the results are shown in Table 3.

The Eviews 12 – Student Lite software was used to test the hypothesis of homogenous non-causality of Dumitrescu and Hulin (2012). The results are presented below in a tabular format.

4 Results and Discussions

As defined in the methodological stage of this study, the selection of the best model goes through the application of the Chow, Hausman, and Breusch-Pagan LM tests. The Chow test, which compares the pooled and fixed effects models, resulted in an $F(26, 370) = 44.17$ and Prob>F = 0.000, implying rejection of the null hypothesis at a 1% significance level, showing that the fixed effects model is preferred over the pooled model. The Hausman test, which compares the fixed effects and random effects models, had a probability Prob>F = 0.0334, indicating rejection of the null hypothesis at a significance level below 5% and hence the preferred model is the fixed effects model.

The Breusch-Pagan LM test, which evaluates the model residuals, helps in the decision between the pooled and random effects models. The result showed that the error variance is different from zero, indicating rejection of the null hypothesis at a 1% significance level (p-value = 0.000). In this case, the random effects model is not appropriate. The analysis of the three tests shows that the model that best fits is the fixed effects model.

The Wooldridge and Breusch-Pagan-Godfrey tests at a 1% significance level indicated the presence of autocorrelation and heteroskedasticity in the model and, therefore, the fixed effects model was estimated with robust error correction. Table 1 presents the coefficient values and the results of the tests performed to define the best model and identify the presence of autocorrelation and heteroskedasticity.

The results indicate that the independent variables explain 86.51% of the dependent variable according to the fixed effects model with robust error correction. The model adjustment is 89.83% among units (R-sq between) and the adjustment is 33.15% within units (R-sq within). Thus, total credit, investment credit, operating expenses, commercialization, harvested area, export value, commodity prices, and the northeast dummy explain 86.51% of the gross agricultural production value of Brazilian states between 2005 and 2020.

Only the variables investment credit, harvested area, and commodity prices were statistically significant at a 1% significance level in the equation estimated by the fixed effects model with robust error correction. The coefficient of investment credit had a positive sign, indicating that a 1% increase in investment credit increases the gross value of agricultural production in Brazilian states by 0.11%. Thus, incentives for rural investment credit are likely to increase the gross value of agricultural production. According to Borges and Parré (2021), this positive relationship is due to credit facilitating the acquisition of capital goods, which contributes to reducing the risks inherent in the commercialization of agricultural products.

In the same perspective, Pintor, Silva, and Piacenti (2014) add that this relationship can be easily explained from the contributions of Schumpeter (1982), who attributed to credit the role of introducing and disseminating innovations in the market. According to Schumpeter (1982), credit provides entrepreneurs with the means to realize innovations, which are essential for the expansion of agricultural activity.

Table 1. Estimation results for Brazilian states, 2005-2020

Variables	*Pooled Regression*	Fixed Effects (FE)	Random Effects (RE)	FE with heteroskedasticity and autocorrelation correction
Constant	10.84016*** (0.5135578)	17.97375*** (0.8317512)	13.5396*** (0.5624852)	17.97375*** (1.121979)
Total_Credit	0.3913408*** (0.0861222)	-0.0891482 (0.0635937)	0.0312249 (0.0655448)	-0.0891482 (0.0594432)
Investiment_Credit	0.0098667 (0.0489552)	0.1120923*** (0.0392557)	0.0906902** (0.0410211)	0.1120923*** (0.0395555)
Operanting_Credit	0.0091886 (0.04809)	-0.0218481 (0.0335429)	0.004107 (0.0354488)	-0.0218481 (0.0446466)
Commercialization_Credit	-0.0213232 (0.0192448)	0.0283317** (0.0146213)	0.0244423 (0.0154489)	0.0283317 (0.0183985)
Harvested_Area	0.3784967*** (0.0469717)	0.4601164*** (0.0635571)	0.6729001*** (0.0548776)	0.4601164*** (0.0983531)
Exports	0.1370119*** (0.0274701)	0.04162 (0.0331859)	0.0144612 (0.0332094)	0.04162 (0.0523489)
Commodities_Price	-0.4870055*** (0.060277)	-0.2707802*** (0.0379625)	-0.3173257*** (0.0402756)	-0.2707802*** (0.0444702)
Nordeste_*Dummy*	-0.4141411*** (0.0528317)		-0.6914237*** (0.138458)	
Observations	404	404	404	404
Groups	27	27	27	27
Periods	15	15	15	15
R-Squared	0.9440			
Adj R-squared	0.9429			
R-sq within		0.3315	0.3116	0.3315
R-sq between		0.8983	0.9496	0.8983
R-sq overall		0.8651	0.9331	0.8651
F-test	832.94	26.21		17.66
Hausman test			15.21	
Breusch-Pagan LM test			659.69	
Chow test		44.17		
Breusch-Pagan/Heteroskedasticity	61,24			
Wooldridge test		28.203		

Statistical significance level: ***1%, **5%.
Note: Values in parentheses correspond to standard errors.
Source: Research findings.

The variable area harvested was also positive, indicating that a 1% increase in the harvested area increases the gross value of agricultural production in Brazilian states by 0.46%, a percentage higher than that of credit. According to Pintor, Silva, and Piacenti (2015), it is due to the expansion of the agricultural frontier into new areas and gains in agricultural productivity, which were made possible by the incorporation of new technologies in the production process and the mechanization of agricultural areas. All of this contributed to the inclusion of new cultivable areas, expanding the total harvested area. The total harvested area in Brazil increased by 32.7% between 2005 and 2020. The highest variations occurred in Amapá (141%), Tocantins (125%), Mato Grosso do Sul (98%), Mato Grosso (91%), Goiás (61%), Pará (55%), and Roraima (52%) (IBGE/SIDRA, 2021).

On the other hand, the commodity price variable, although significant, had a negative sign, unlike expected, indicating that a 1% increase in the price reduces the gross value of agricultural production by –0.27%. This negative relationship for Brazilian states can be attributed to the level of aggregation that the variable carries, as it is the average of agricultural product prices, incorporating products that are not part of the states' production. In summary, a positive impact was observed only for investment credit on the gross value of agricultural production, and no significant relationship was observed for the other modalities.

These results corroborate the findings of Gasques, Bacchi, and Bastos (2017) and Pintor, Silva, and Piacenti (2015), who also identified a positive relationship between rural credit and the gross value of agricultural production. It indicates that rural credit is an important policy for agricultural activity growth in Brazilian states, as credit, especially investment credit, helps to modernize and revitalize production.

4.1 Dumitrescu and Hulin Granger causality test

The Dumitrescu and Hulin (2012) Granger causality test was performed to verify the causality relationship between the studied variables. One and two lags were employed since this test is sensitive to the number of lags used, and the results are presented in Table 4.

The presence of unit roots was checked before performing the causality test, using the LM, Pesaran, and Shin (2003), and Levin, Lin, and Chu (2002) tests. The results are shown in Table 2. The null hypothesis of the presence of a unit root in the series is rejected for both tests. Thus, the analyzed series is assumed to be stationary at the level.

Table 2. Lm, Pesaran, and Shin and Levin, Lin, and Chu unit root tests

Variable	Lm, Pesaran, and Shin W-stat[1]		Levin, Lin, and Chu t[2]	
	Statistic	**Prob.**	**Statistic**	**Prob.**
LTotal_credit	-10.4661	0.0000	-13.8796	0.0000
LInvestment_credit	-10.0075	0.0000	-13.4821	0.0000
LOperating_credit	-9.6265	0.0000	-13.0725	0.0000
LComercialization_credit	-10.4956	0.0000	-14.0262	0.0000
LVBP	-12.5613	0.0000	-16.0932	0.0000

(1) individual unit root process.
(2) common unit root processes.
Note: Null hypothesis: the presence of unit root in all panels.
Source: Research results (2021).

Table 3 shows the cointegration tests. The null hypothesis is that there is no evidence of cointegration for the N cross-sectional units. The Pedroni test (1999) rejects the null hypothesis at a 1% significance level, confirming that the series are cointegrated. Only the Panel v-statistic and Panel rho-statistic were not significant at acceptable levels of significance. However, the existence of a cointegration process is confirmed by the Kao test (1999), which also suggests that the variables are cointegrated since the cointegration coefficients obtained by the residual lag method are significant at a 1% significance level. Similarly, the Fisher-Johansen test (1995) rejects the null hypothesis, indicating the presence of one to three cointegration vectors.

Table 3. Pedroni, Kao, and Fisher-Johansen cointegration tests

Pedroni's residual cointegration test				
	Statistic	**Prob.**	**Weighted Statistic**	**Prob.**
Alternative hypothesis: common AR coefficient (within dimensions)				
Panel v-statistics	-1.9045	0.9716	-3.6811	0.9999
Panel rho-statistics	-0.5509	0.2908	0.4932	0.6891
Panel PP-statistics	-9.0632	0.0000	-7.3138	0.0000
Panel ADF-statistics	-8.3875	0.0000	-6.7085	0.0000
Alternative hypothesis: individual AR coefficient (across dimensions)				
Group rho-statistics	2.0998	0.9821		
Group PP-statistics	-9.8015	0.0000		
Group ADF-statistics	-6.9070	0.0000		
Kao's residual cointegration test				
	Coefficient	Standard error	t-statistic	P-value
ADF			-15. 5375	0.0000
Resid(-1)	-1.258122	0.0550	-22.8364	0.0000
Fisher-Johansen cointegration test				
Hypothesized No. Of CE(s)	**Fisher Stat.**	**Prob.**	**Fisher Stat.**	**Prob.**
None	107.0	0.0000	83.46	0.0000
At most 1	294.9	0.0000	261.1	0.0000
At most 2	162.6	0.0000	140.7	0.0000
At most 3	42.18	0.0010	41.53	0.0013
At most 4	23.29	0.1796	23.29	0.1796

Source: Research findings.

Table 4 shows the results of the homogeneous non-causality tests. The results for the causality relationship between the gross value of agricultural production and total credit, considering a lag and acceptable levels of significance, indicate non-rejection of the null hypothesis of homogeneous non-causality. Therefore, there are no causality relationships for all cross-section units.

The analysis of the causal effects of credit on investment, working capital, and marketing showed a unidirectional causal relationship from the gross value of agricultural production to investment credit, considering a lag and a significance level of 10%. It means that the gross value of agricultural production causes investment credit in the Granger sense, indicating rejection of the null hypothesis of homogeneous non-causality. In other words, there is a heterogeneous causality relationship between the gross value of agricultural production and investment credit for Brazilian states.

Considering working capital credit, a bidirectional causal relationship was observed between working capital credit and the gross value of agricultural production, i.e., the parameters are different from zero in both regressions. Therefore, the working capital credit causes the gross value of agricultural production in the sense of Granger, and the gross value of agricultural production causes the working capital credit in the sense of Granger at a 1% significance level. Thus, the null hypothesis of homogeneous non-causality is rejected, indicating that there is a heterogeneous causality relationship between working capital credit and the gross value of agricultural production for all Brazilian states.

On the other hand, commercial credit presented a unidirectional causal relationship with the gross value of agricultural production, starting from the gross value of agricultural production to commercial credit. It means that the gross value of agricultural production for Brazilian states causes commercial credit in the sense of Granger. Thus, the null hypothesis of homogeneous non-causality is rejected at a 5% significance level and a lag.

Table 4. Granger causality test by Dumitrescu and Hulin (2012) for Brazilian states, from 2005 to 2020

Null Hypothesis: homogeneous non-causality	Result		
	W-Stat.	Zbar-Stat.	Prob.
Lags: 1			
LVBP does not cause LCr_total homogeneously	2.7835	4.1349	4.E-05
LCr_total does not cause LVBP homogeneously	4.0103	7.3381	2.E-13
LVBP does not cause LCr_investment homogeneously	0.5613	-1.6675	0.0954***
LCr_investment does not cause LVBP homogeneously	1.0341	-0.4329	0.6651
LVBP does not cause LCr_custeio homogeneously	6.1947	13.0422	0.0000*
LCr_custeio does not cause LVBP homogeneously	8.7133	19.6185	0.0000*
LVBP does not cause LCr_commercialization homogeneously	0.4404	-1.9606	0.0499**
LCr_commercialization does not cause LVBP homogeneously	0.8315	-0.9836	0.3253
Lags 2			
LVBP does not cause LCr_total homogeneously	3.9755	2.1148	0.0344**
LCr_total does not cause LVBP homogeneously	4.9840	3.6337	0.0003*
LVBP does not cause LCr_investment homogeneously	1.2650	-1.9676	0.0491**
LCr_investment does not cause LVBP homogeneously	1.4504	-1.6884	0.0913***
LVBP does not cause LCr_custeio homogeneously	6.9038	6.5253	7.E-11
LCr_custeio does not cause LVBP homogeneously	9.2897	10.1188	0.0000*
LVBP does not cause LCr_commercialization homogeneously	1.5467	-1.5204	0.1284
LCr_commercialization does not cause LVBP homogeneously	2.3929	-0.3915	0.6954

*Note: "L" indicates that the variable is in logarithmic form. Level of significance: *1%, **5%, ***10%.
Source: Research results.

Considering two lags, the causality relationship changes, indicating that, for some variables, the causality relationship can only be verified after a period of time. This is the case for the variable 'total credit' and 'gross value of agricultural production.' They showed a bidirectional causality relationship when considering two lags. It means that both total credit causes Granger-wise gross value of agricultural production, and the gross value of agricultural production causes Granger-wise total credit. In this case, the null hypothesis of homogeneous non-causality is rejected, indicating that there is a heterogeneous causality relationship between total credit and the gross value of agricultural production for all Brazilian states. Therefore, total credit and gross value of agricultural production only show a causality relationship after a period of time, not an immediate effect.

The analysis of the causality relationship between 'investment credit' and 'gross value of agricultural production' showed a bidirectional causality relationship considering a 10% significance level, and a unidirectional causality relationship was observed at the maximum significance level of 5%, starting from the gross value of agricultural production towards investment credit. Therefore, the null hypothesis of homogeneous non-causality is rejected, assuming that there is a heterogeneous causality relationship between states.

On the other hand, 'working capital credit' showed a unidirectional causality relationship with 'gross value of agricultural production,' starting from working capital credit towards the gross value of agricultural production. It indicates that working capital credit causes Granger-wise gross value of agricultural production. Contradicting the relationship verified for one lag, which pointed to a bidirectional causality relationship, it means that the causality relationship changes over time, and credit unidirectionally causes the gross value of agricultural production. Thus, the null hypothesis of homogeneous non-causality is rejected, that is, there is a heterogeneous causality relationship between working capital credit and gross value of agricultural production. Finally, considering two lags, commercialization credit did not show a significant causality relationship with the gross value of agricultural production.

These results are consistent with the findings of Borges and Parré (2021), who analyzed the agricultural GDP using the conventional Granger causality test and identified a significant causal relationship between rural credit and agricultural GDP, confirming the existence of temporal precedence between the variables, starting from rural credit to agricultural output. A similar relationship was also found for investment credit, which showed unidirectional causality from credit to agricultural output.

Regarding operating credit, the aforementioned authors also identified a bidirectional causal relationship between operating credit and agricultural output. On the other hand, regarding commercial credit, the authors identified no causal relationship with agricultural output, as they were unable to reject the null hypothesis of non-causality by Granger.

However, Reginato, Cunha, and Vasconcelos (2019) used the sum-difference method and identified no causal relationship from rural credit to GDP, regardless of the number of lags considered in the model. However, the authors identified a significant causal relationship from GDP to rural credit for one and two lags. Similarly, Cavalcanti (2008) only identified Granger causal relationships starting from agricultural GDP to rural credit, regardless of the lag level included in the model.

Thus, there is a temporal precedence between the gross value of agricultural production and investment and operating credit, regardless of the number of lags included in the model. The causal relationship is unidirectional, starting from the gross value of agricultural production to investment credit, considering one lag, and bidirectional, considering two lags. Operating credit presented a bidirectional causal relationship with the gross value of agricultural production, considering one lag, and unidirectional for two lags, with the causal relationship starting from operating credit towards the gross value of agricultural production.

Final Considerations

This study aimed to analyze the impact of rural credit on the gross value of agricultural production in Brazilian states from 2005 to 2020. Additionally, it sought to verify the existence of a causal relationship between these two variables to identify if incentives for rural credit policy can generate significant increases in the gross value of agricultural production in Brazilian states.

The results indicated a positive and significant impact of credit for investment and harvested area on the gross value of agricultural production, showing that the gross value of agricultural production increases by 0.11% for every 1% increase in credit for investment, while the gross value of agricultural production increases by 0.46% for every 1% increase in the total harvested area.

The commodity price variable had a negative sign, indicating that the gross value of agricultural production reduces by 0.27% for every 1% increase in price. According to Pintor, Silva, and Piacenti (2015), this negative relationship can be attributed to the aggregation level of the variable, which includes all commodity prices and can cause divergent considerations. In general, a positive relationship is expected so that a positive variation in price would also lead to a positive variation in the gross value of agricultural production. Moreover, the average prices cannot capture the regional particularities of all Brazilian states because it is a regional analysis. In addition, the average does not include the price of agricultural products that are not classified as commodities and are important in the production of the states.

Granger causality tests by Dumitrescu and Hulin (2012) confirm the existence of temporal precedence between the gross value of agricultural production and credit for investment and financing, regardless of the number of lags included in the model.

A unidirectional causal relationship was observed for investment credit, starting from the gross value of agricultural production towards investment credit. Considering two lags, the causal relationship becomes bidirectional so that investment credit causes Granger-wise the gross value of agricultural production, just as the gross value of agricultural production causes Granger-wise the investment credit.

In contrast, with one lag, operating credit showed a bidirectional causal relationship with the gross value of agricultural production, and a unidirectional causal relationship with two lags, with the causal relationship starting from operating credit towards the gross value of agricultural production. In other words, operating credit causes Granger-wise the gross value of agricultural production.

On the other hand, different causal relationships were observed considering one and two lags, indicating that for some variables, the causal relationship can only be verified after a period of time. As observed for total credit and gross value of agricultural production, which only showed a causal relationship with the inclusion of two lags, a bidirectional causal relationship was verified in this case. The null hypothesis of homogeneous non-causality was also rejected, indicating that there is a heterogeneous causal relationship for all Brazilian states.

Therefore, the results confirm the hypothesis that credit has a positive impact on the gross value of agricultural production, with different causal relationships between credit modalities. It leads to the conclusion that incentives for rural credit policy are relevant for the growth of the agricultural sector since temporal precedencies between variables are confirmed in different directions, in addition to a significant and positive coefficient for investment credit.

Finally, an analysis of the causal relationship by Brazilian state and/or macro-regions is suggested for further studies to explore and identify regional particularities, allowing the identification of the causal relationships for each specific federative unit or macro-region. Given the regional differences in income, production, and credit supply, the responses regarding the gross value of agricultural production and the causal relationships may differ among the states. Identifying these differences would be important to improve credit policy and direct it more assertively toward regional needs. In addition, further investigations are suggested into the reasons why operating and commercialization credit did not have a significant impact on the gross value of agricultural production in Brazilian states.

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Submitted on: 07/07/2022 Approved on: 28/03/2023